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THE TECHNOLOGICAL COMPETENCE OF EUROPEAN SEMICONDUCTOR PRODUCERS

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Abstract

A new method for assessing changing corporate technological competence and the impact of European collaboration policies is developed and applied to the case of the European semiconductor industry. The data indicate that in relation to US and Japanese firms, European technological competences improved in the latter half of the 1980s. Increasingly, European firms adopted pro-active technology partnerships (joint ventures and technology exchanges) as opposed to passive activities (second-sourcing and licensing). Although the European research and development subsidy programmes of the 1980s attempted to remedy Europe's weaknesses, there are reasons for questioning the policy methods chosen. European companies followed their own directions, withdrawing from major projects as market circumstances changed and forming alliances with non-European firms, despite the wishes of policy makers. Collaboration policies based on ownership run a danger of encouraging sub-optimal partnerships among European followers at the expense of ventures with non-European technology leaders. Given the risks of high cost close-to-market subsidies, policies for the 1990s should seek to encourage technology transfer from non-European partners and to stimulate healthy competition within Europe. To continue as major contenders in the international market, European firms should pursue outward-looking strategies and continue their technology partnerships with global leaders.

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Abbreviations

ASIC	Application specific integrated circuit
IC	Integrated circuit
CMOS	Complementary metal oxide semiconductor
DRAM	Dynamic random access memory
EC	European Community
EPROM	Erasable programmable read only memory
ESPRIT	European Strategic Programme of Research in Information Technology
JESSI	Joint European Sub-micron Silicon Initiative
MPU	Microprocessor unit
R&D	Research and development
SRAM	Static random access memory

Introduction

Semiconductors or 'chips' are the main hardware input for consumer electronics, telecommunications, computers and office automation products. They are also widely used in industries such as aerospace, defense, instrumentation, medical equipment and automotive. European suppliers of semiconductors and electronics systems have lagged well behind their US and Japanese competitors. During the 1980s the European Community (EC)[1] promoted a series of semiconductor research and development (R&D) programmes in the belief that subsidy and collaboration would strengthen European firms' technical competences and improve their competitive performance in both semiconductors and electronics systems.

This paper analyses the changing technological competences of European-owned chip producers during the 1980s and assesses the impact of EC support policies on Europe's semiconductor industry[2]. It presents data on the flows of technology into and out of Europe using a new method designed to generate a rough measure of the technological competence of firms in relation to international competitors. While the data can only afford a partial measurement, they indicate that European firms grew in relative technological competence during the 1980s. They also suggest that the EC programmes had little real effect on corporate strategy or performance. Therefore, policy makers would be wise to question their policies of subsidy and collaboration.

Part 1: Europe's Poor Performance In Semiconductors

As far as market size (measured by consumption) is concerned, the European market is smaller than that of the US and Japan. In 1991 it was estimated at US$11.5 billion (19% of the world market), compared with US$ 23.7 billion for Japan (38%) and US$ 17.8 billion for the North America (29%) (ICE 1991 p1-8). As far as production is concerned, since 1980 European companies' share of world output has oscillated around 10% of the total. According to the consultancy firm Dataquest Inc., in 1980 Europe's share was 13%. This dropped to 11% in 1983 and 1984 (Wall Street Journal, 19 June 1989, p1). In 1988 and 1989 the EC share was around 9.5%. This rose to around 10% in 1990 (including intra-company sales) (ICE 1991, p1-19).[3]

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[1] As most of the paper is concerned with the 1980s, the term 'EC' is used throughout. Since November 1993 the European Union has subsumed the European Community.

[2] The term 'European semiconductor industry' refers only to European-owned firms. However, as the paper argues, the EC has benefited considerably from non-European firms operating in Europe and outside.

[3] Note that regional sales refer to ownership of production by company, not location of production. That is EC output would include the non-EC production of European firms.

Comparing consumption with production, Europe's share of world consumption has remained at around 20% since 1982, while production has averaged around 10% per annum. Around one half of Europe's semiconductor needs have been satisfied either by imports or by foreign firms operating within Europe. The EC's balance of trade in semiconductors (including integrated circuits, optoelectronics and discrete devices) deteriorated from a deficit of around US$2.6 billion in 1984 to one of approximately US$4.2 billion in 1988. Since then it has worsened steadily.

Europe's fragility in semiconductor supply is also reflected in the ranking of leading companies. For instance in 1990 and 1991 only one firm, Philips of Holland, was in the top ten (at number ten). In 1991 STM (SGS-Thomson) ranked number 15 and Siemens number 17. Over the past ten years or so Philips has been the only European firm constantly in the top ten list of firms (Dataquest, cited in Electronics Times 16 January 1992, p6).

Table 1: European-Owned Companies' Sales of Integrated Circuits* 1990 (US$ million)

Company	Headquarters	Total sales
Philips-Signetics	Holland	1175
SGS-Thomson	Italy-France	1175
Siemens	FRG	1000
GEC-Plessey	UK	340
ITT	France	210
Telefunken	FRG	120
MHS Semiconductor (Matra)	France	105
Mietec	Belgium	92
Austria Micro Systems	Austria	63
EMM	Switzerland	48
ABB HAFO	Sweden	42
ES2	France-Uk	29

* This definition excludes discrete devices (which represent an average additional 17% of chip sales for large companies).

** Includes Inmos

*** Includes Marconi

Source:ICE (1991, p2-39)

Table 1 presents total integrated circuit sales of the twelve largest European-owned suppliers of chips. The three largest firms, Philips-Signetics, SGS-Thomson (including Inmos) and Siemens accounted for sales of US$3,350 million in 1990, around 75% of total European production. Other firms were very small in comparison. European semiconductor output is not only small but comparatively backward. Around 37% of sales in 1990 were in relatively mature 'bipolar' devices compared with 63% in the more advanced 'MOS' (metal oxide semiconductor) technology. This compares with worldwide output of 24% in bipolar in 1990 and 75% in MOS (ICE 1991, p5-1).

To understand why Europe lags behind it is helpful to outline a simple typology of corporate strategies in semiconductors. As Table 2 shows, there are four main generic types of strategy (although considerable overlap exists). Type 1 strategies are followed by the major US 'merchant' volume producers. They produce both standard chips and ASICs (semi customised and customised semiconductors) for the external chip market. Strategies are based on cost leadership, product innovation and market agility.

Table 2: Typology of Corporate Strategies in Semiconductors

StrategicType	Market Orientation	Product Markets	Examples of Firms
1. Merchant Volume	Outward-looking	Standard Custom/ASIC	Texas Instruments Motorola
2. Merchant Niche	Outward-Looking	Custom/ASIC	Inmos ES2
3. Vertically Integrated	Inward-Looking	Standard Custom/ASIC	IBM, dec Siemens
4. Vertically Intergrated	Outward-looking	Standard Custom/ASIC	Fujitsu Samsung

Source: author's analysis and industry interviews, 1991 to 1994

Type 2, merchant niche suppliers, tend to supply ASICs to the open market. Many cluster in Silicon Valley. Being small, they have limited access to capital and have to be highly innovative to survive. They either aim for a large share of one or two major niches (eg, Inmos in fast SRAMs or transputers) or they supply a wide range of smaller niches, moving quickly once the majors enter their territory (eg, Plessey in ASICs). Survival of these firms depends upon fast reaction to shortening product life cycles, flexibility and software capabilities.

Type 3 firms include the very large vertically integrated firms of the US (eg, IBM, DEC, and AT&T). They are 'inward looking' as they tend to make chips for their in-house use, rather than the open market. Some produce chips in very large volumes (eg, IBM), while others focus on specialist/ASICs for systems (eg, Ericsson). Large volume strategies are based upon process innovation and economies of scale.

Type 4 firms consist mainly of Japanese and South Korean corporations. Although similar in structure to type 3 firms, they tend to combine open market (ie, outward-looking) competition with in-house production. This strategy has proved very successful for Japanese firms. The rigours of competing in the open market prevent inertia and force companies to maintain leading edge technology.

Within this typology large European firms such as Siemens, Philips and GEC have traditionally been an extreme form of type 3 (inward-looking, vertically integrated). During the 1970s, Europe's large firms focused on in-house, specialist needs, selling mostly within national boundaries. Technological levels were generally behind the frontier set by US firms. State procurement encouraged the inward-looking strategies of the chip makers, while European government's supported their national champions by protection and subsidy. By the early-1980s, Europe's chip industry was technologically backward and uncompetitive especially in mainstream, commodity chip areas.

During the mid-1980s several European firms attempted a resurgence by shifting from strategic type 3 to type 4. Siemens, for example, embarked upon a major corporate restructuring which placed great emphasis on chip capabilities and selling on the open market. Thomson, SGS, and Philips also attempted to build up their technological capabilities to world class levels and to increase their exports. At the same time, several pan-European Government programmes of R&D collaboration were set up to support the EC firms in the belief that this would assist competitiveness. The Governments of France, the UK, Italy, West Germany and the Netherlands also channelled resources directly to their leading manufacturers. EC Programmes included ESPRIT 1, 11 and 111 (the European Strategic Programme of Research in Information Technology). Eureka was initiated by France in 1985 and included 12 Community states, six EFTA countries and Turkey.

ESPRIT 1 began in February 1984 as a pre-competitive R&D programme.[4] The largest area was the Advanced Microelectronics Programme (AMP) which accounted for about 25% of allocated funds. The AMP's aimed to ensure a healthy supply of chips for Europe in sufficient quantity and at competitive prices(CEC 1987 p1). Following ESPRIT 1, ESPRIT 2 ran from 1987 to 1992. Within it, the Microelectronics and Peripherals sub-programme aimed to develop advanced ASICs and spoke of ensuring the commercial exploitation of R&D results from ESPRIT 1.

In the latter half of the 1980s major European firms formed strategic alliances, backed by the EC. Rationalisations and mergers also occurred. SGS-Thomson formed a pan-European venture (STM), while Siemens and Philips collaborated in key semiconductor projects. Major events in the UK included the takeovers of Ferranti by Plessey, Plessey by GEC/Siemens and Inmos by SGS/Thomson.

Within Eureka the Megaproject was the first large scale technology partnerships between Siemens and Philips. Siemens and Philips spent a total of roughly US$1.0 billion on sub-micron (leading edge) chip technology. The Dutch and West German Governments funded roughly one third of the total cost. The Megaproject was a four year collaborative R&D venture targeted at the one megabit and four megabit DRAM chips. In 1986, SGS and Thomson applied to Eureka for US$255.0 million to jointly develop four megabit and 16 megabit memories (EPROMs) and ASICs. Each company committed an estimated US$200.0 million to the venture. In April 1987 the two firms launched a jointly-owned pan-European chip company (SGS-Thomson).

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[4] The term 'pre-competitive' has never been adequately defined. In practice it refers to both basic and applied R&D. In the case of the EC programmes it included applied development work, linked to specific products and processes (see below).

The largest pan-European chip initiative was JESSI (the Joint European Sub-micron Silicon Initiative), set to run from 1988 to 1995 under Eureka. It included funding for the Siemens-led 64 megabit DRAM project and the SGS-Thomson 64 megabit EPROM and the Philips 0.5 micron SRAM project. JESSI's committed spending was roughly US$4.2 billion over an eight year period (Electronics Times, 27 June, 1991). Although JESSI was part of Eureka, the EC also assisted the project under its umbrella Framework Programme. Half of the costs of JESSI projects were borne by participating firms, a quarter by participating national governments and the remaining quarter by the EC. Many of the chip projects in ESPRIT 3 were linked to the Eureka/JESSI projects.

Part 2: Research Objectives, Methods And Data

Data on 161 major European technical and equity ventures carried out during the 1980s (120 technical agreements and 41 mergers, acquisitions and joint ventures) were gathered and analysed. The data deal only with published ventures. Non-reported (eg, minor, confidential or secret agreements) are not included. The ventures reported are self-selected by firms, and important to the extent that the firms publicised their ventures and the industry press chose to report them. It can be assumed that most important European ventures over the period are included.[5] The types of agreement reported are those most common to externally oriented competence accumulation in the chip industry. Although the data provide only a partial indicator of technological accumulation (ie, externally oriented), they are probably a more effective indicator than the normal patent, bibliometric or citation indices.[6]

Data up to 1984 are from a study by Haklisch et al (1986). Primary data for the period 1985 to 1991 were gathered from industry journals and databases. An initial data base search (Predicast Prompt and Textline) proved unsuitable for the exact categorisation described below. Therefore a detailed examination of industry journals was undertaken. The main sources were Electronics Times, Electronics Weekly, Electronics and Electronics Business. Information was also gathered via interviews with industrialists over the period 1991 to 1994.

The data were divided into two periods: 'before' and 'after' the start of the European programmes in 1984, in order to assess any changes in the nature and number of agreements. The data were classified according to the four major types of technical agreements common in the semiconductor industry:

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[5] Unless reported in the press as major events, the data exclude R&D agreements entered into under EC programmes and Eureka. The reasoning is that only if they were publicised and reported upon did they constitute ventures directly important to the strategy of the firm concerned and *vice versa*.

[6] Patents measures are dubious, as semiconductor firms have very different propensities to patent, especially European producers of military and telecommunications systems. Bibliometric data are also problematic as much of the near-market technology work of Europe's firms is not published.

SS = second sourcing agreement; refers to a specific, formal agreement; may occur within or in conjunction with a TE or JV; refers to current technology.

L = one way flow of technology (product or process); similar to SS but not necessarily one specific product; can refer to a process or group of products; refers to current technology.

TE = technology exchange; refers to a two-way technology exchange agreement, broader than an SS but can specify a specific product, process or family of either; refers to current technology.

JV = joint venture or strategic partnership; refers to the development of a generic process technology suitable for a range of products (or a major new product design); refers to future technology developments.

The four types of agreement include the majority of external corporate activities for building technological competences in the chip industry. Shifts between the four types of agreement over time are a useful indicator of changes in the capability of firms. For instance, SS and L are relatively passive forms of technology acquisition (from the recipients' perspective), usually involving a senior and junior partner. The senior or dominant partner sells technology to a junior or weaker partner. In contrast, TE and JV represent pro-active forms of external venture. Under TE and JV arrangements both firms share or swap their existing competences or assets (TE) or develop a new technology (JV) for the benefit of both firms.

A move from SS and L towards TE and JV on the part of EC firms would suggest an increase in competence, both in relation to non-EC firms and in relation to previous performance. The converse would also be the case. For instance, Japanese firms began their competence-building via SS agreements with US firms. Today, they also engage in a wide range of JVs and reverse SS agreements to US firms. This reflects the growing competence of Japanese firms in relation to US firms (and in relation to their prior abilities).

For the purposes of this paper it is important to assess whether the share of pro-active partnerships increased, as European firms attempted to build up their competences in the latter half of the 1980s. If this occurred, it would indicate an increase in relative competence on the part of European firms.

Each agreement was also assessed according to the international (geographical) direction of technology flow to assess trends over time. The data fell into five categories:

E = intra-European technology flow[7]

E*/EC = intra-European technology flow sponsored by the EC or Eureka

I = inward (international) technology flow (to Europe from overseas)

O = outward (international) technology flow (to overseas from Europe)

I/O = technology flow both directions, in and out (both parties gained technology).

[7] Intra-European technical ventures are not double counted but treated as single agreements in the analysis below, according to the first named firm in the data.

It was hoped that categorising the data according to the geographical direction of technology flow would show whether technology tended to flow into or out of Europe, whether there had been changes over time and whether the EC programmes had made an impact.

Part 3: Main Findings

The data were examined according to country, firms, technical and non-technical (equity) agreements, semiconductor product type, trends over time, motivations, choice of partner and direction of technology flow. Table 3 presents the technical (non-equity) ventures for the period 1980 to 1991 by year.

A total of 120 technical agreements was reported over the 1980 to 1991 period, distributed fairly randomly through time on a year-by-year basis, although more were concentrated in the latter half of the 1980s. As would be expected, the major European firms (Siemens, Thomson, SGS, Philips and GEC) accounted for most technical ventures over the period. The pan-European ventures SGS-Thomson and ES2 became very active during the post 1984 period. Other firms typically engaged in one or two ventures, with a small number undertaking three or four technical operations each.

Table 3: External Technical Ventures, 1980 to 1991, Agreements by Year

Year	Number of Agreements
1980	4
1981	13
1982	11
1983	4
1984	11
1985	7
1986	8
1987	9
1988	9
1989	9
1990	16
1991	13
undated	6
Total	120

<u>Findings: 1980 to 1984</u>

A total of 48 technical agreements was reported over the first five year period, 1980 to 1984, averaging nearly ten per annum. As Table 4 shows, most agreements were with US firms (29 or 60%). Ten (21%) were with Japanese firms; only four were intra-European. In addition, three took place with South Korea, one with Hong Kong and one with Canada. The data show that European electronics firms turned outwards to non-European (especially US) firms to acquire semiconductor technology.

Table 5 looks at the direction of technology flow over the period 1980 to 1984. The largest category of technology flow was into Europe (23 or 50%) from non-European firms. The next major category was joint technology flows in and out of Europe (13 or 28%). Only four intra-European ventures occurred out of 46, of which one was sponsored by the EC (the Philips-Siemens Megaproject). Only six cases (13%) were one-direction flows out of Europe.

Clearly, technical joint ventures with foreign firms were already a significant feature of the European chip industry in the early 1980s. European firms gained access to important new product technologies (eg, MPUs, custom chips, gate arrays and memories) and processes (eg, CMOS). Domestic European firms relied mainly on US firms for technology, although Japanese companies such as NEC and Toshiba also supplied technology.

Table 4: Analysis by Partner Country: 1980 to 1984

Partner Country	Number of Agreements	Percentage
United States	29	60%
Japan	10	21%
Intra-European	4	8%
Other	5	10%
Total	48	

Table 5: Analysis by Direction of Technology Flow, 1980 to 1984

Direction	Code	Number	Percentage
Into Europe	(I)	23	50%
Jointly with Non-Eur	(I/O)	13	28%
Intra-European	(E)	4	9%
Out of Europe	(O)	6	13%
Total accounted for		46	
Not accounted for	(n/a)	2	

Second-sourcing was not the main function of external technical ventures, although some European firms second-sourced US products. A look through the individual agreements (not presented here) confirms that during the early 1980s European firms' strategies were designed mainly to meet the needs of in-house systems (e.g. MPUs for telecommunications) rather than the merchant market. This corresponds to the inward-looking, type 3 approach in the classification in Part 2 and contrasts with the outward-looking market strategies of Japanese systems firms. Europe was the main beneficiary in terms of technology acquisition. Very few ventures involved outflows of technology from Europe. Most joint ventures resulted in technology flowing into Europe (50%). Inflows and joint developments together amounted to 78% of all agreements.

To sum up, over the period 1980 to 1984, left to the market, European firms tended to form technical agreements outside Europe, rather than within. This reflected the technological and commercial lead of US firms over European companies. Europe's firms acted on the belief that the best option for technological acquisition was via foreign ventures, rather than intra-European agreements. Over the period 1980 to 1984 the US was a valuable source of support for the competence-building activities of Europe's semiconductor and electronics systems developers.

Findings: 1985 to 1991

During the seven year period 1985 to 1991 total agreements numbered 74. This represents an average of ten per year, a slight increase over the earlier period 1980 to 1984 (eight per annum). As Table 6 shows, the largest category of agreements was with US firms (as in the early 1980s). However, the share of US agreements declined from 60% to 47% from the earlier period. Another difference between the two periods was the large increase in intra-European partnerships. These increased from only 8% in 1980-84 to 30% in 1985-91. Intra-European ventures therefore overtook Japanese ones as the second largest category of technical ventures.

Part of the reason for the increase in intra-European ventures was EC financial support and political persuasion under the EC R&D Programmes. Seven of the 22 agreements were EC sponsored. Removing EC projects reduces the intra-EC share to 21% of the total, roughly equivalent to the Japanese share. This still represents an increase in intra-EC ventures over the period 1980 to 1984. The residual increase was probably due to market rationalisation, EC policy effect, and as argued below, an increasing competence on the part of EC firms.

Table 6: Analysis by Partner Country: 1985 to 1991

Partner Country	Number of Agreements	Percentage
United States	34	47%
Japan	17	23%
Intra-European	22*	30%
Other	0	
Total	73**	

* of which 7 EC sponsored

** one of which was a three way agreement

Did EC Programmes alter the pattern of technology flow?

Given the beneficial flows of technology from the US to Europe in the early 1980s, one critical question is whether or not the EC Programmes altered (or distorted) the 'natural pattern' of technology flow from the US. If EC policies subsidised an increase in intra-European collaboration, then it could be argued that the EC distorted the natural pattern of inward technology flows from the US into Europe. Or put another way, the EC could be said to have subsidised sup-optimal intra-EC partnerships into existence, thereby damaging EC firms' competence-building (as well as wasting EC funding).

It is not possible to answer this question fully from the data alone, as what would have occurred in the absence of the programmes is impossible to judge. However, the following three factors indicate that the EC Programmes had a neutral or positive rather than a negative effect on competence-building. (Whether they delivered value for money and whether their costs outweighed their benefits are two other important questions, outside the scope of this paper).

First, as noted above, EC policy did not stem EC-US technology flows. This remained the largest category in both periods. The policy may have substituted some intra-EC agreements for EC-US flows, but there remained a substantial flow. Second, during the latter period there was a large shift away from inward flows towards joint development projects, reflecting an increased confidence of European firms compared with the early period.

Table 7 shows inward technology flows for 1985-1991 (down from 50% to 13% compared with 1980-1984). This was compensated for by an increase in joint technology developments (I/O), with both European firms (up from 9% to 28%) and non-European firms (up from 28% to 56%). EC supported projects accounted for seven (around 35%) of the intra-European projects. Other causes of intra-European ventures were corporate efforts to rationalise the fragmented European market prior to 1992 and the growing capabilities of EC players.

Table 7: Analysis by Direction of Technology Flow, 1985 to 1991

Direction	Code	Number	Percentage
Into Europe	(I)	9	13%
Jointly with Non-Eur	(I/O)	40	56%
Intra-European	(E)	*20	28%
Out of Europe	(O)	3	4%
Total accounted for		72	

* of which seven were EC-sponsored

The increase in joint developments indicates a growing technological competence on the part of European firms. This was probably due to: (a) previous inflows of technology from the US and, to a lesser extent, Japan; (b) the training of Europeans within US subsidiaries; and (c) EC technology strengthening programmes.

Third, examining the data according to passive versus active technology agreements confirms that European firms increased their pro-active abilities to develop technology in the latter period. Table 8 shows that joint ventures (JVs) for future technology development were the largest category for both periods, followed by two way technology exchanges (TEs). Adding JVs together with TEs gives an idea of overall pro-active technology partnerships. Table 8 indicates: (a) a predominance of JVs and TEs in both periods; and (b) an increase in JVs and TEs in the latter period (from 61% to 77%). This indicates a shift towards pro-active technology engagement, suggesting an increase in local technological capability relative to overseas competitors in the latter half of the 1980s.

Table 8: Analysis by Agreement Type: 1980-84 and 1985-91 (Number of Agreements and Percentages)

Type of Agreement		1980 to	1984	1985 to	1991	Change over time
Joint Venture	(JV)	25	40%	41	45%	+5%
Technology Exchange	(TE)	13	21%	29	32%	+11%
License	(L)	13	21%	17	19%	-2%
Second Source	(SS)	11	18%	4	5%	-13%
Totals		62*		91*		

* totals are larger than the numbers of agreements, as some agreements involved more than one type of technical arrangement.

European Equity Operations

From 1977 to 1984, 13 European equity ventures were reported (including mergers, acquisitions and divestitures). All the ventures were with US firms, mostly 100% takeovers. Most takeovers were by large EC companies of relatively small US companies, except for Signetics and Fairchild, which were both major US chip operations. No takeovers of European firms by US companies occurred. Japanese firms were not engaged in any successful, reported equity operations.

Motivations on the part of European companies were as follows. First, companies wished to gain access to American technology and skills. Second, they wished to access the large US market. Large European chip suppliers benefited from the open approach of the US to high technology takeovers. Interestingly, Siemens - not a company reputed for expansion via acquisition - engaged in more take-overs than any other European company. Like other European firms, Siemens utilised US takeovers to enhance its semiconductor operations.

After 1984 a total of 27 European equity ventures took place. Again, large firms accounted for most operations, although the new firm ES2 accounted for 5 (19%) of the total. The two main types of equity venture were: first, takeovers of US firms by European companies (ten in all); and second, intra-EC mergers and acquisitions (14 in all). A further three were divestitures of US firms, reflecting European efforts to rid themselves of unprofitable or difficult-to-manage ventures.

As for the takeovers of US companies, most were small or weak American firms being purchased by or receiving capital injections from larger European firms. The motivations, again, were probably to access chip technology and to gain entry to the US market. As in the earlier period, a wide range of chip technologies were accessed via these agreements.

The data on intra-European equity operations demonstrate a major rationalisation of European chip operations during the 1985 to 1991 period. A new pan-European company was formed between SGS of Italy and Thomson of France. Several relatively small UK chip operations were taken over by GEC to form one consolidated company. The financially weak, but technologically impressive, Inmos (UK) was sold to STM, strengthening the latter's product range.

The new start-up ES2 obtained substantial financial backing (in the region of US$50 million) from various European firms and the Eureka Programme. Managers for ES2 were recruited from US firms, including Texas Instruments. Other US-trained European managers took prominent positions in firms such as SGS, Thomson and Plessey. As discussed elsewhere, management training within US firms was an important source of indigenous competence building by European firms in the 1980s (Hobday, 1992).

Among the probable causes of post-1984 intra-European mergers, acquisitions and investments were: (a) a renewed commitment on the part of firms to chip technology; (b) a belief in the benefits of economies of scale; (c) the growing competence and ambitions of European firms; (d) EC financial support and political encouragement; and (e) rationalisation of the EC market prior to 1992.

Part 4: Government Policies And Corporate Strategies

It was suggested above that it is necessary to question EC policies which might distort the natural international flow of technology to European firms. Overall, the quantitative data reflect European companies' relative technological weakness in semiconductors and their need to keep up with world leaders through alliances.

When there is potential conflict between corporate strategy and EC policy, the qualitative evidence indicates that firm strategy takes priority over government policy. This is an important point, as it suggests that individual European governments and the EC should be very cautious about attempting to influence the direction of corporate strategy.

The cases of Siemens and Philips indicate that large firms keep their technology options open, despite their expressed commitments to EC policies and pan-European partnerships such as JESSI. For example, EC policy clearly aimed to build up pan-European alliances in chips. However, this did not inhibit Siemens from beginning a very large joint venture with IBM for 64 Megabit DRAMs in 1990 (costed at over US$1 billion). Siemens decided that its better option was to form a venture with IBM rather than with STM of Europe. Indeed, Siemens rejected an EC policy idea (also favoured by STM) of building a giant European chip operation through a merger between STM's and Siemens' chip operations. Earlier, Siemens accessed DRAM technology from Toshiba of Japan, again despite its involvement in European DRAM programmes. Also in conflict with EC policy aims, Philips decided to withdraw from a large SRAM project in JESSI after making losses in its semiconductor division.

With respect to EC policy, these events indicate that large firms retain control over decision making, regardless of EC policies, wishes and subsidies. This is, of course, quite proper. Only firms are in a position within the market to take strategic decisions (rightly or wrongly). This strongly suggests that the EC and individual European governments should be very wary of influencing near-market decision making among firms. Governments are not in a position to decide on such matters.

Policy documents from the EC have argued that R&D projects should get closer to the market to ensure the exploitation of research (eg, CEC, 1991). Some academic analysts (eg, Delapierre and Zimmerman, 1991) also argue for a strong state role in support of European electronics firms. However, the above examples of Siemens and Philips 'going their own way' indicate that near-market policies are highly risky, both in terms of project completion and likely return (financial, market share or technological) on capital invested. Firms may decide to opt out of ventures as market circumstances change, as occurred in the case of Philips and GEC (the large recipient of UK Government and ESPRIT funding). GEC withdrew from several near-to-market projects (under the Alvey Programme) as a result of a changes in corporate strategy and priority (Guy et al, 1991).

A further reason for questioning support for near-market projects is the opportunity cost involved in funding large firms' technological activities. Less risky areas which could suffer as a result of the opportunity cost of large, near-market projects include: basic research, firm-university programmes, long-term standards projects, human resource development, training and infrastructure projects. As conventional 'public good' areas these are likely to provide benefits without distorting the market.

There are other economic reasons for questioning near-market support to large European firms. First, it is contrary to the fair trading principles and free market ethos of GATT and the Treaty of Rome. Although such treaties do allow for state subsidies in special circumstances it is doubtful whether the semiconductor industry would qualify. Second, near-market research does not have the economic justification of externalities or public good benefits. Third, by establishing or accepting subsidy as a normal practice, the EC could stimulate a 'subsidy race' between the EC, Japan and the US, and help promote sub-optimal government policies worldwide; in the case of the US, for example, part of the justification for the large Government funded SEMATECH Programme was the European programmes of subsidy and collaboration such as ESPRIT and Eureka. Fourth, EC firms such as Philips, Siemens and GEC are clearly large enough to make their own decisions and fund their own investments in R&D.

Conclusion

This paper introduced a new method of assessing corporate technological competence and applied it to the European semiconductor industry. Although such indicators can never be conclusive, they suggested that European firms' technological competences improved in relation to non-European firms in the latter half of the 1980s. During this period, there was a shift away from one-way inward (international) flows of technology towards joint, two-way technology ventures with foreign firms, signifying a growing competence among European firms. Firms adopted increasingly pro-active partnerships (joint ventures and technology exchanges) as opposed to passive activities (second-sourcing and licensing).

Throughout the 1980s, US and, to a lesser extent, Japanese firms continued to be an important source of technology for European-owned companies, both through technical ventures and via take-overs (of US companies). Europe's domestic firms benefited from the

US's open approach to high technology takeovers. Conversely, there were no significant take-overs of European chip firms by US or Japanese companies.

Intra-European equity ventures showed a major restructuring of Europe's chip industry. The national champions of the 1970s gave way to pan-European champions, led by Siemens of Germany, STM of France and Italy, and Philips of the Netherlands. The EC R&D support programmes of the 1980s coincided with European firms' new strategies. Firms and EC policy makers together acted to remedy Europe's weaknesses in chip technology and the deteriorating market position of EC firms.

With hindsight, there are reasons for questioning the policy methods chosen, especially the large scale investments in near-market process technologies. Although firms contributed to EC policy decisions, European companies followed their own directions, withdrawing from major projects when it suited them. They also formed alliances with non-European firms despite the expressed wishes of EC policy makers. Indeed, non-European firms continued to be an important source of technology throughout the 1980s and into the 1990s, a feature not recognised sufficiently in policy discussions.

The evidence suggests that policy makers should think again about close-to-market subsidies for European-owned chip suppliers. Near-market collaborative projects are intrinsically high cost and high risk. With rapidly changing market circumstances, firms can and do change their strategies mid-stream, leaving projects and policies in difficulty. In addition, there is a danger that such policies might encourage sub-optimal partnerships among EC followers at the expense of ventures with non-EC technology leaders. European-owned firms are now sufficiently large and competent to make their own decisions without subsidy or direction. Policies should seek to encourage direct foreign investment and to stimulate healthy competition wtihin Europe to ensure an adequate supply of semiconductors to user firms.

Despite the recession and financial difficulties of the early 1990s, the evidence shows that EC electronics firms have improved their technological competence. Compared with the 1970s they have reversed their image of inertia and technological backwardness. To continue as major contenders, they must pursue outward-looking strategies and continue their technology partnerships with international market leaders.

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